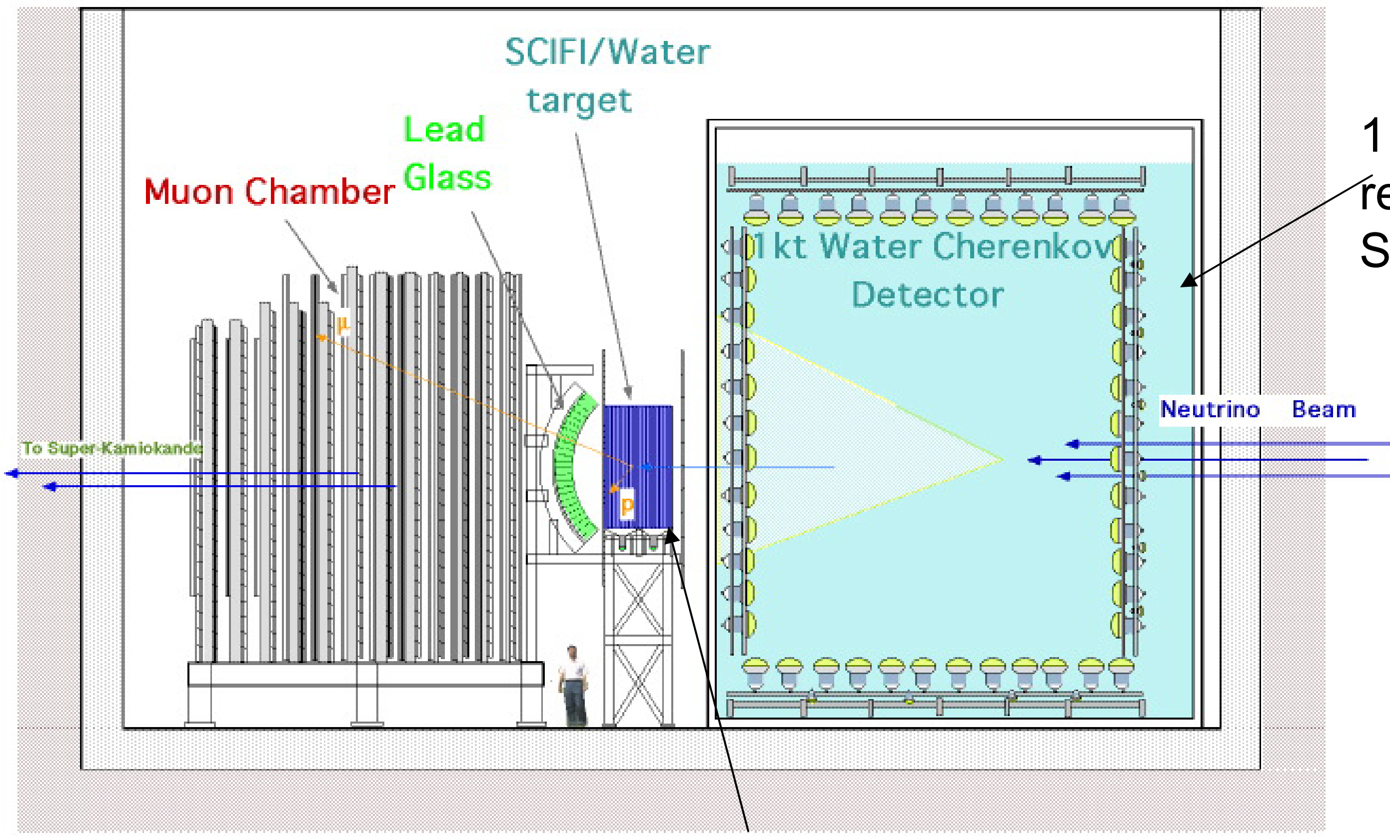
Near Detector Physics Working Group Summary

Gallagher, Harris, Pearce

Let’s Start With a Story…

The Tale of a Near Detector

Near Detector Physics Group
MINOS Meeting
September 2003, FNAL



1 kton H_20 detector replicates the SuperK far detector

Fine grained detector measures sub-relativistic particles, has good vertex resolution and tracking.

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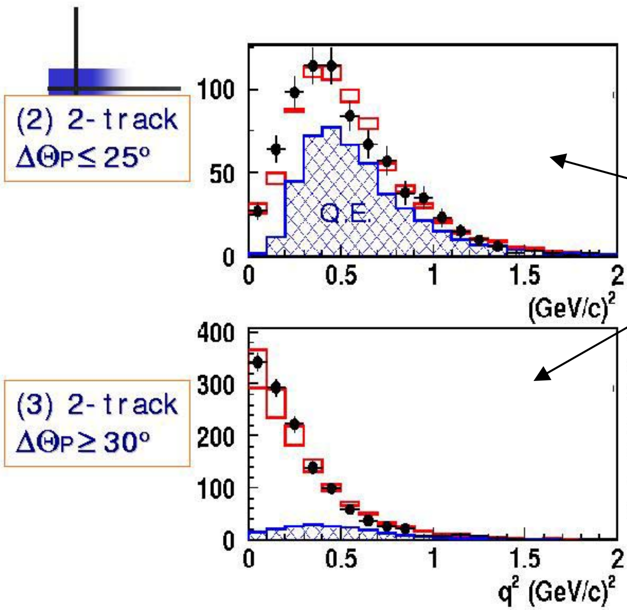
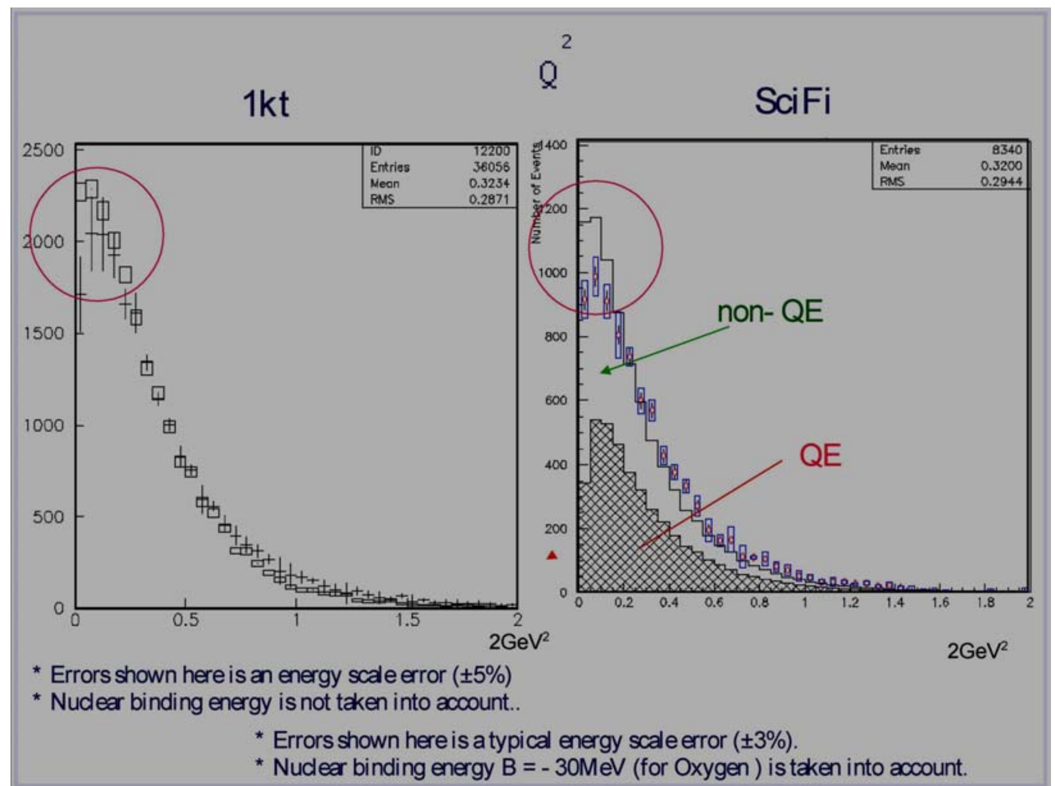
- Q^2 distributions of 2-track samples (K2K)

T.Ishida@nuint02



Data from their 1 kt H_2O Near Detector and Monte Carlo do not agree.

Measurements in the SciFi detector allow them to break the distribution out into QE and non-QE components.



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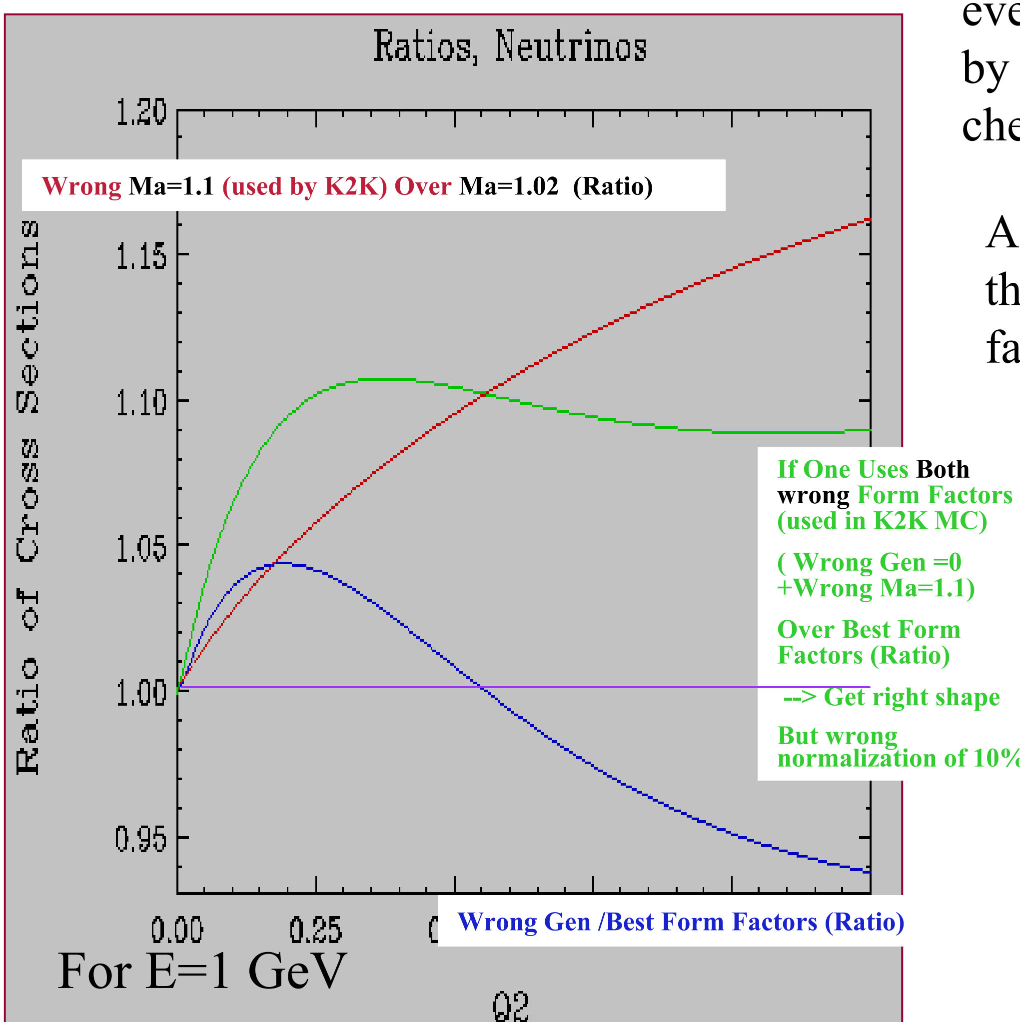
K2K was able to fit this data by using different M_A ($1.02 \rightarrow 1.10$) for resonance events and altering the QE/non-QE fraction by 0.93. Studied old BNL bubble checking for consistency.



Arie Bodek claims that the real problem is that all neutrino MC's use outdated form factors, in particular non-zero G_E^n.

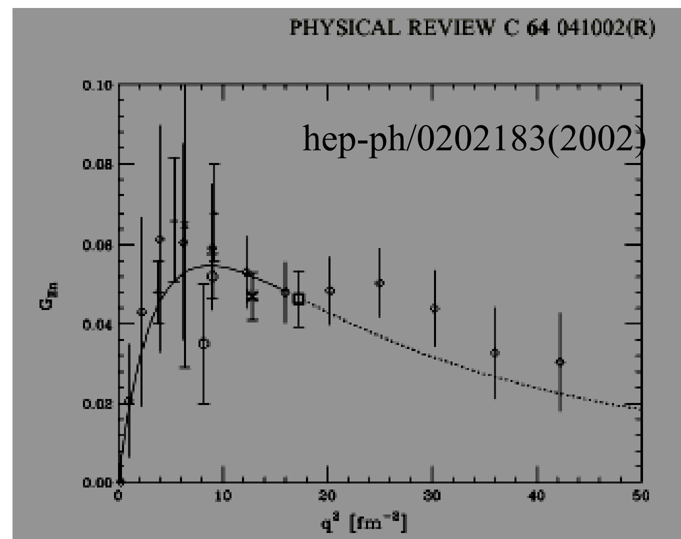


FIG. 3. The G_{En} extracted from the C2 data (◇). Also shown are the values obtained from double-polarization experiments, and the Galster parametrization with its extrapolation into the region not covered by previous experiments (dotted line).

The Tale of a Near Detector

Arie's Conclusion:

Can fix the Q2 dependence either way (by changing mA or using correct vector form factors). However the overall ***cross sections will be 10-15% too high if one chooses wrong***

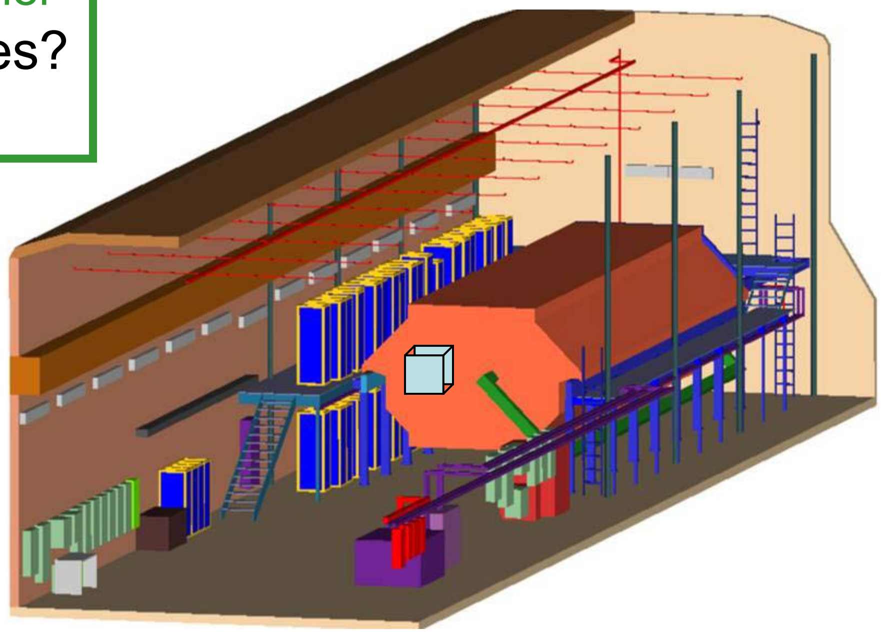
Although the story is not completely resolved there are several lessons:

1. Having different measurements in the near location sampling different energies / interaction processes is important for MC tuning. High resolution devices are particularly valuable. ← Debbie (beam changes) ← Hugh /Geoff (fine grained ND)
2. Old bubble chamber data is still important and useful. ← Costas
3. The need to maintain consistency with electron scattering results. ← Hugh

Improved Near Detector

There are a fair number of spare components available after the completion of the CalDet runs. Could these possibly be used to good use in the near hall?

- What spares / leftovers exist?
  Geoff Pearce /Gary Drake
- How could they be best used?
  Dave Boehnlein / Hugh Gallagher
- What are the physics capabilities?



Objectives

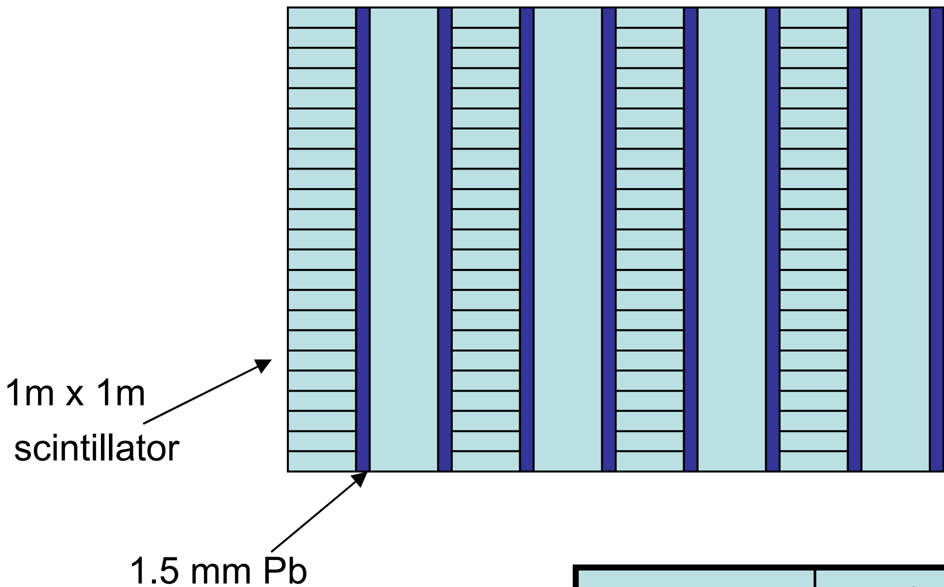
- Fundamental Physics Measurements?
  - Rates are too low
- Direct Relevance to Oscillation Analysis
  - Separation of ν_e events based on clean topological cuts?
- Monte Carlo Confirmation
  - Detector is used as a vertex detector
  - Improved topological separation
  - Improved resolution

Usefulness is limited by the small mass and containment – incomplete kinematic coverage for all processes.

Possible Detector

In a first iteration, did simulations in a detector comprised entirely of scintillator planes. Two obvious problems: small mass and limited containment.

Even with a fully active detector around ¼ of quasi-elastic events are single tracks.



Possible detector optimized for good tracking / topological discrimination as well as ν_e identification.

30 planes/view alternating views X/Y
1.5 m upstream of the front face of the ND
44 kg / plane, 2.66 tons total
…

	ρ (plane)	λ_I/plane	X_o/plane	dE/dx/plane
Scintillator	1.032 g/cm^3	0.012	0.024	2.52 MeV
MINOS	5.9 g/cm^3	0.16	1.52	31.5 MeV
FGND	2.38 g/cm^3	0.03	0.56	6.35 MeV

ν_μ CC Quasi-Elastics

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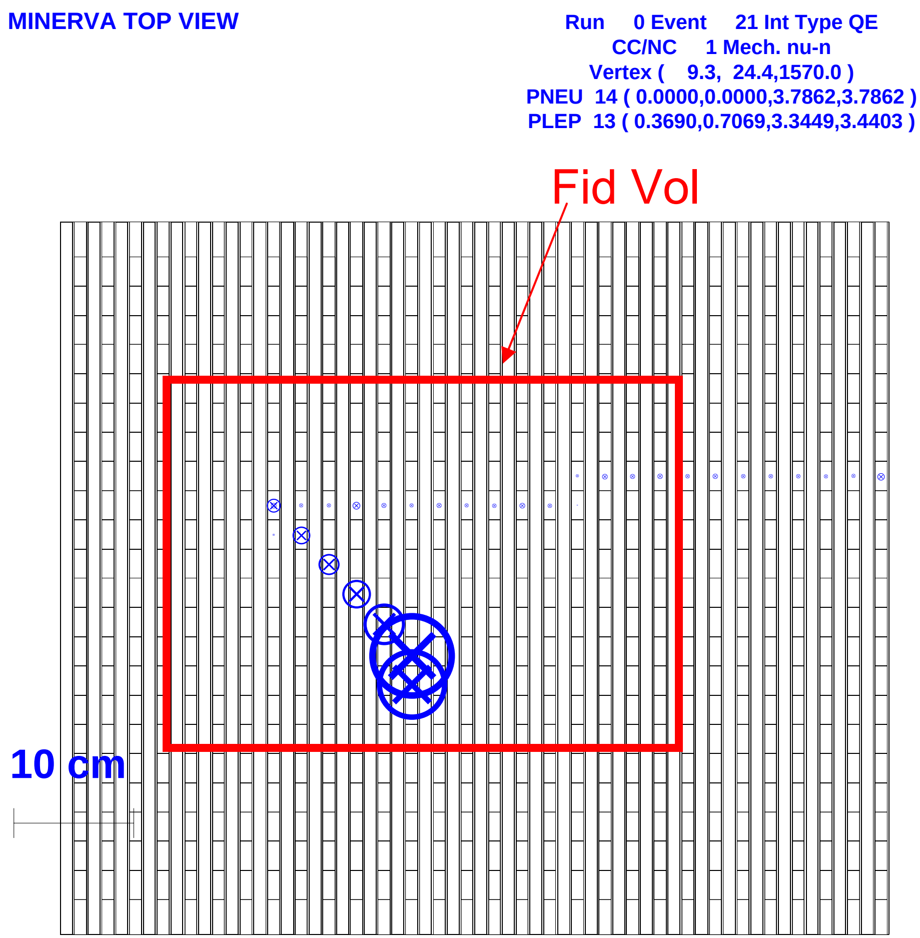
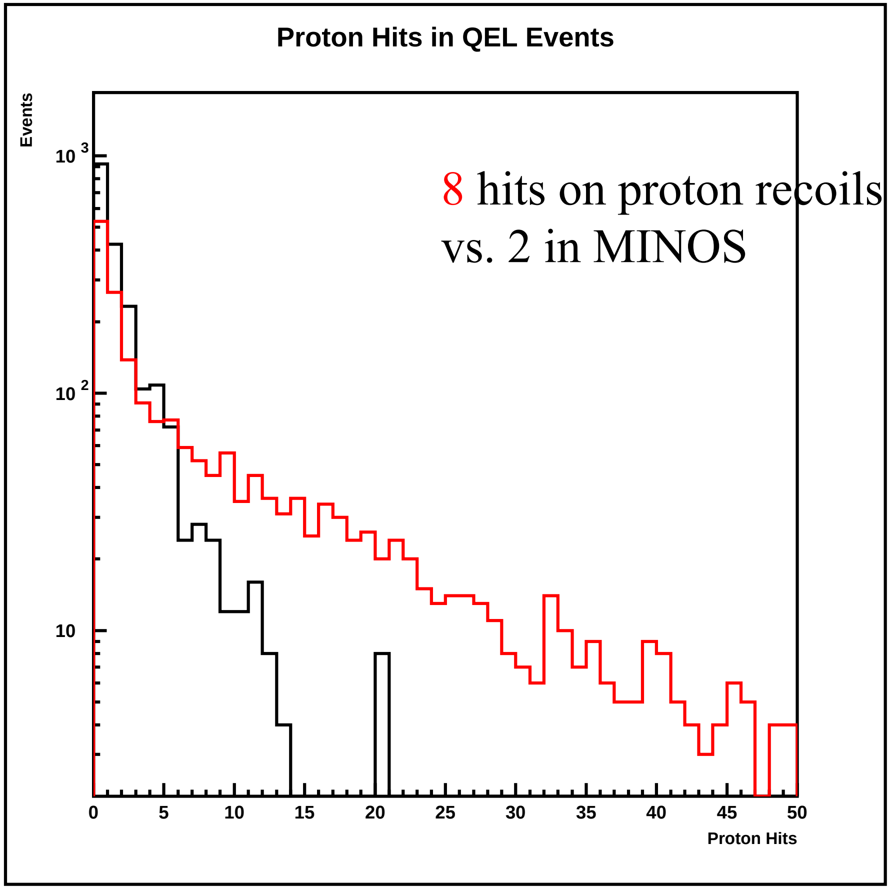
MINERVA MC: S. Boyd and D. Casper





Fiducial volume is 0.33 tons.

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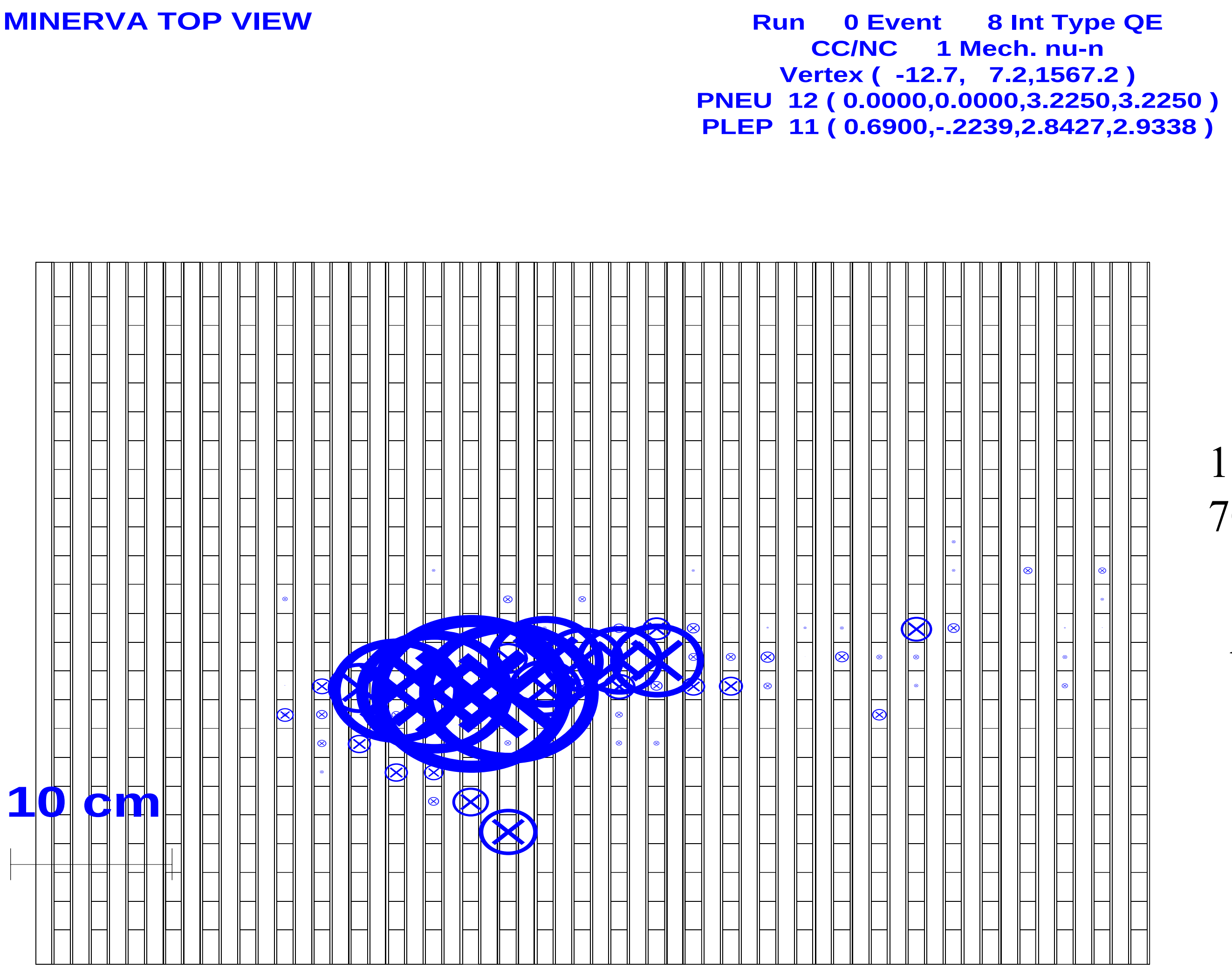
ν_e CC QEL



1.4 GeV electron shower
700 MeV proton

ν_e CC QEL

ν_μ CC DIS

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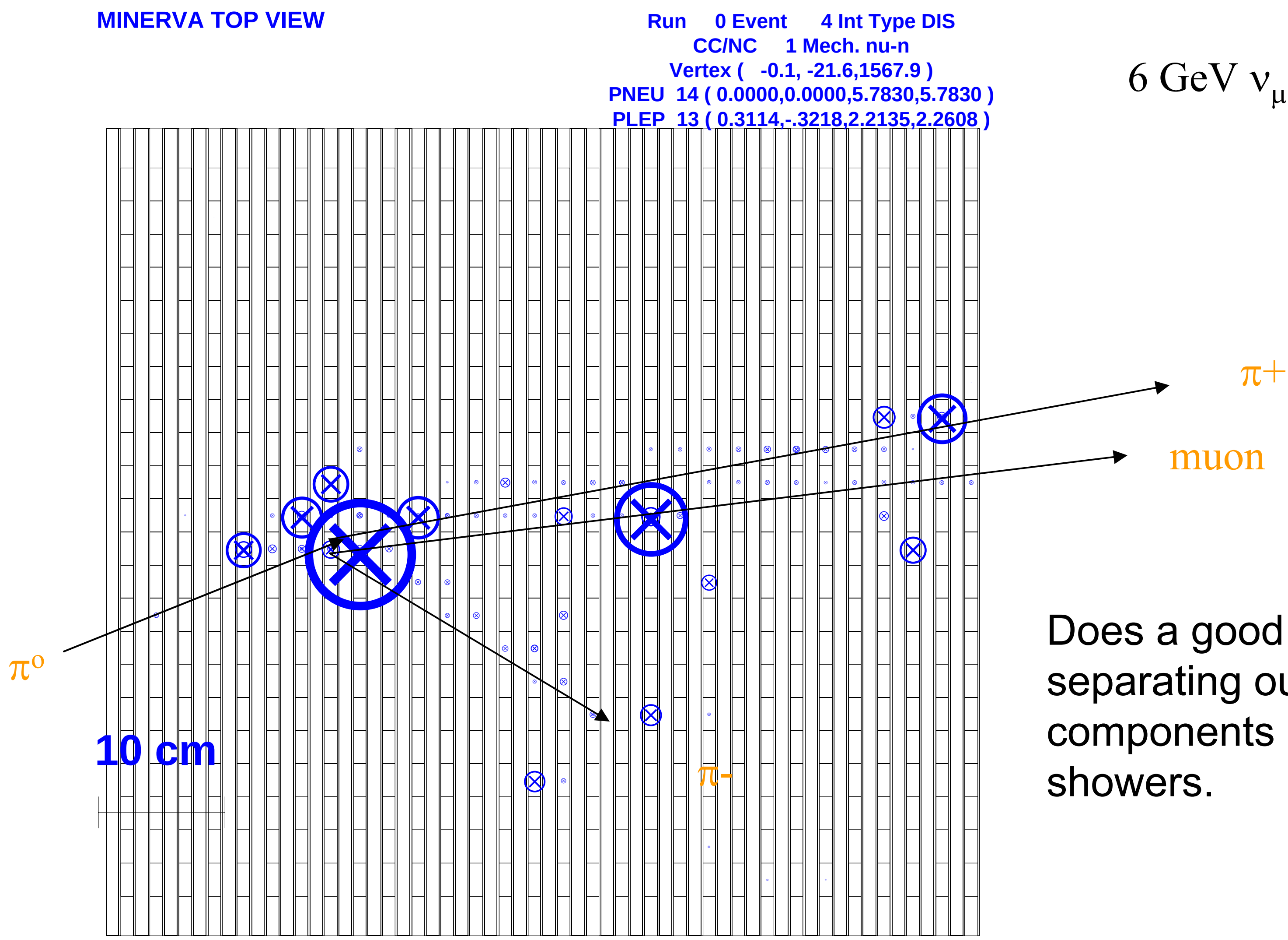

6 GeV ν_μ DIS

Does a good job of separating out e/h components of hadronic showers.

Event Rates

Event Rates: events/ yr in the FGND Fid Volume

	Elastic	CC QEL	NC INEL	CC INEL
ν_e	30	80	250	840
ν_μ	3800	9735	19100	63700

Assumptions: Readout electronics for the entire 60 planes

No vetoing issues for this fiducial volume and analysis …

Containment (ν_μ CC)

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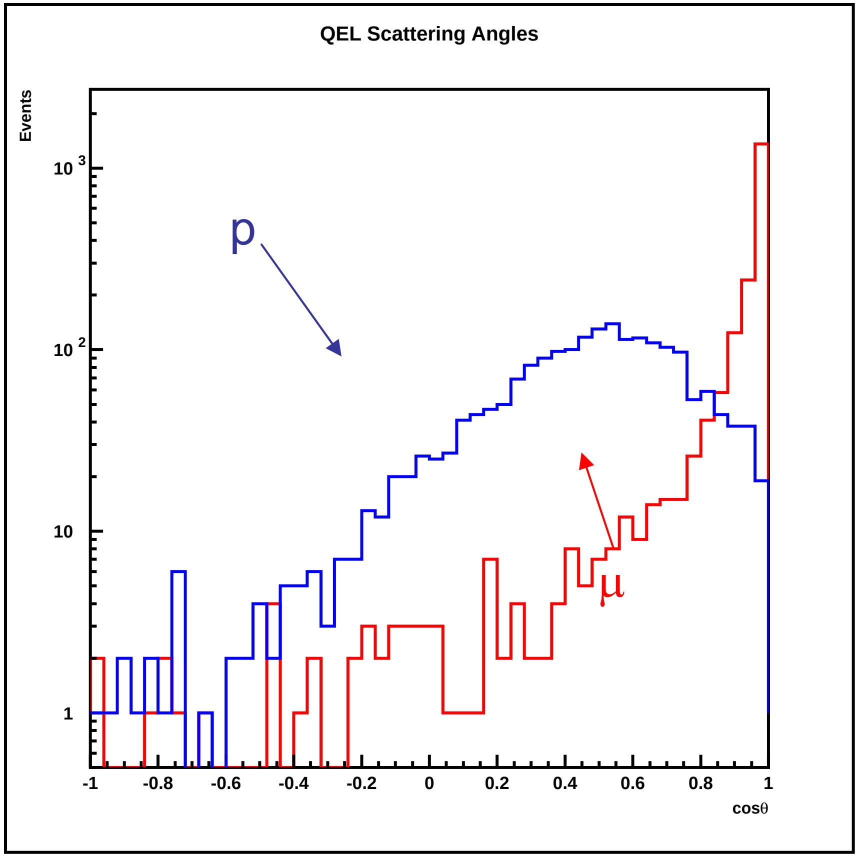
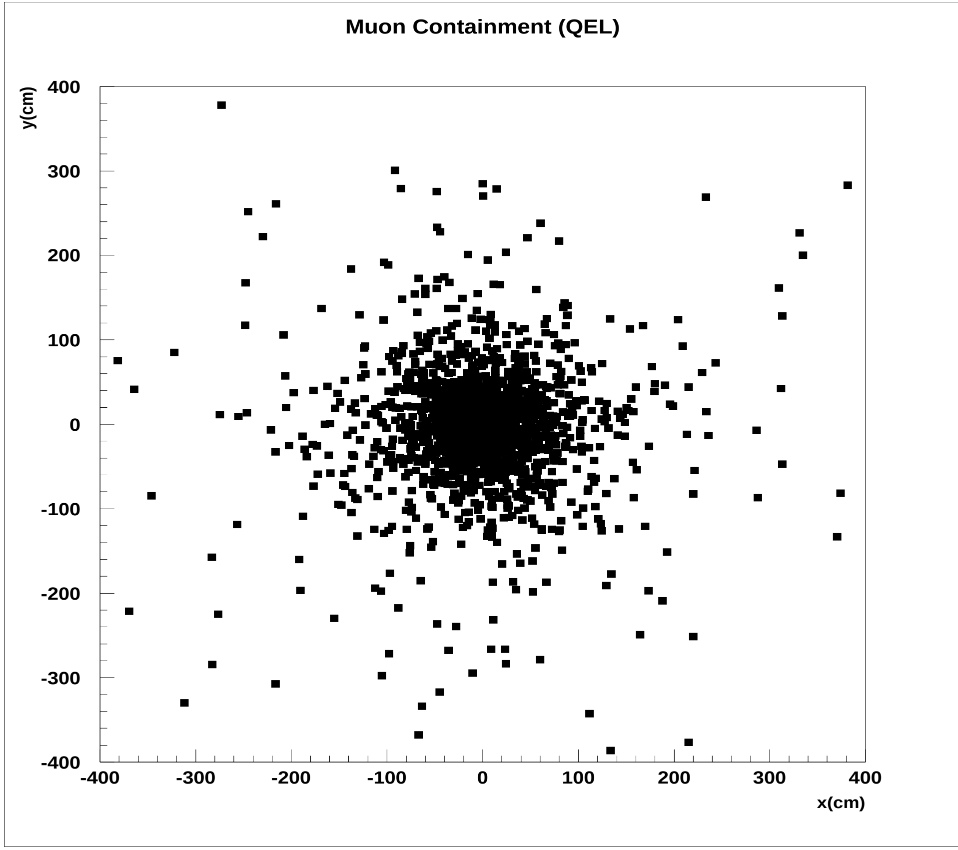
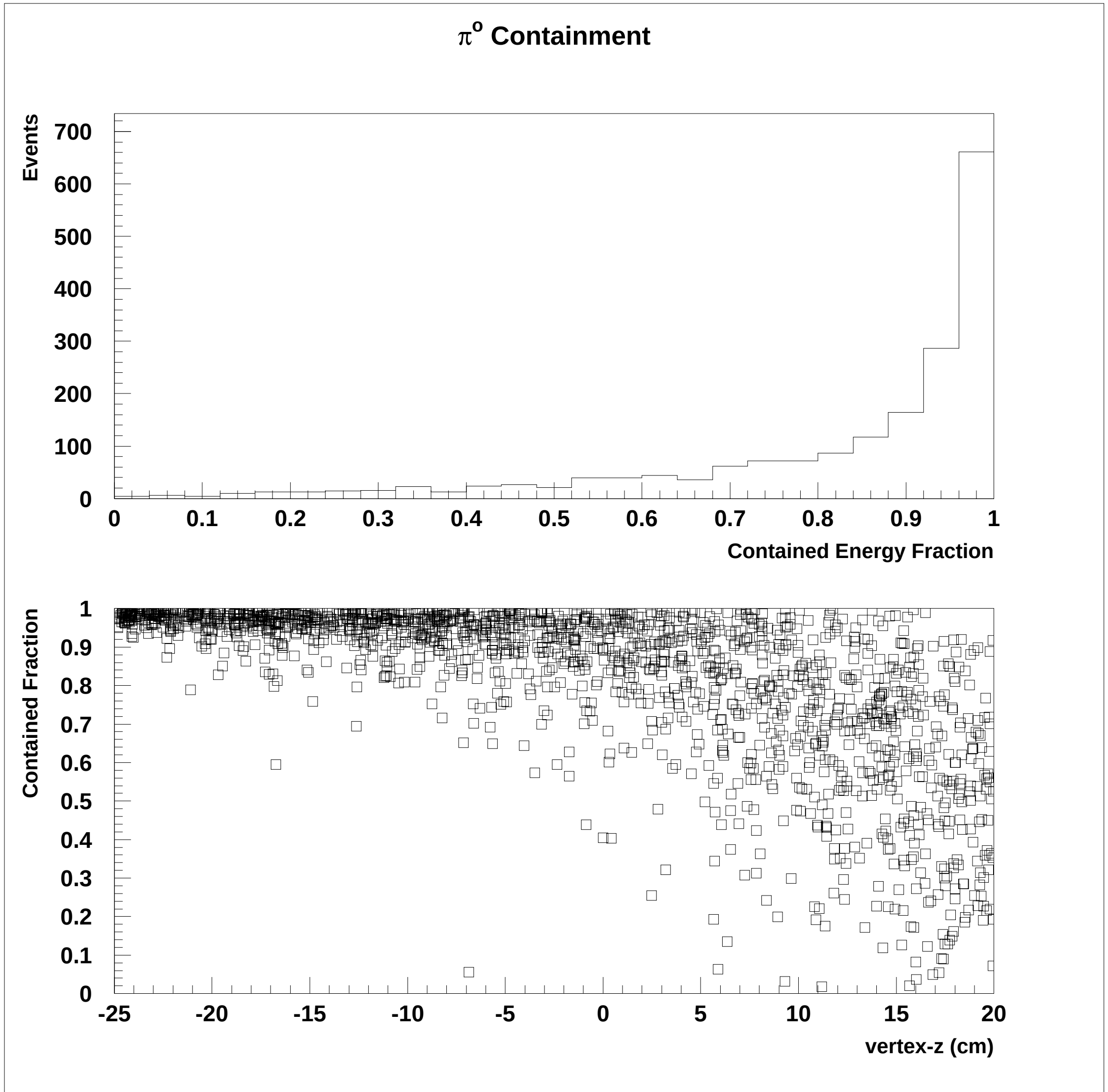




75% of the QEL produced muons are measured in the MINOS near detector.

60% overall for ν_μ CC.

Pion Containment



For this particular fiducial volume ½ of coherent π^o have > 90% energy containment.

ν_e Measurement

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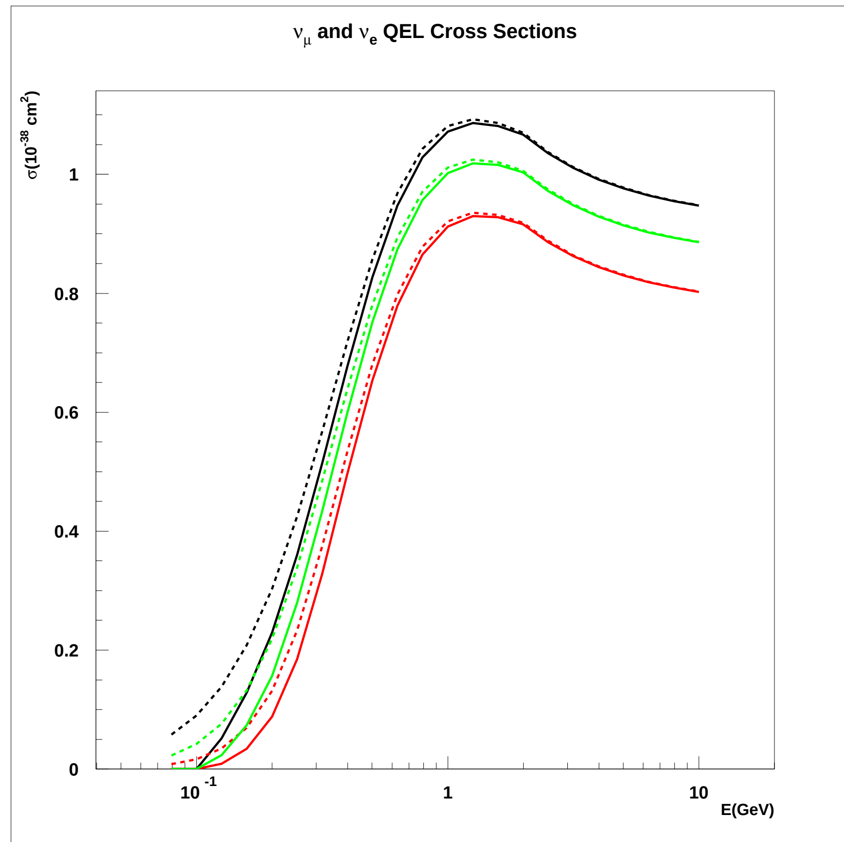
Cleanest sample for ν_e identification are QEL-like events.

$$N_e = \int \phi_e \, \sigma_{QEL} \, A^e_Q + \phi_e \, \sigma_{INEL} \, A^e_{Inel} \, dE$$

$$N_m = \int \phi_m \, \sigma_{QEL} \, A^m_Q + \phi_m \, \sigma_{INEL} \, A^m_{Inel} \, dE$$

$$\frac{\phi_e}{\phi_m} = \frac{N_e}{N_m} \, \frac{\sigma_{QEL} \, A^e_Q + \sigma_{INEL} \, A^e_{Inel}}{\sigma_{QEL} \, A^m_Q + \sigma_{INEL} \, A^m_{Inel}}$$

~1. Differences are on the order of 10% and would need to be known to 30% For a 3% systematic uncertainty.



Uncertainty on this ratio from the beam group will be around 5% post-MIPP →

400 ν_e events for a 5% statistical error.

Spares

- Geoff did an inventory of available "warm spares"
  - Sufficient PMTs and bases (24 M64s)
  - Sufficient Alner boxes (16 CalDet and 3 ND spares)
  - DAQ spares sufficient to readout an extra master crate
  - Bottleneck is front end electronics, enough exists to read out 932 channels (36 planes)

	spares	required
Master Crate	**1**	**1**
Master	**8**	**12**
Minder	**58**	**90**
Menu+QIE	**932**	**1440**

Serious reservations were raised about the use of the ND electronics spares in this fashion:

- If this detector is actually useful, one wouldn't want to pull electronics out when needed
- Level of spares (10%) is based on a model for support that would be very different from this.

Cost (not including development) is around $250 / channel.

Conclusions on FGND

- Not Crazy
  - Independent, high resolution samples important for tuning MC
  - Good e/h separation, π^{o} measurement
  - Possibility of a direct ν_e measurement in several years running

- Not Free
  - Bare minimum cost using spares would be on order 100k$
  - More realistic is several 100k$ for new electronics and some vetoing up front.

Portable Outriggers?

Possibility put forward by D.Boehnlein, a variant of the outrigger concept presented by Vittorio in 2000.

Put the steel back in to make 2 1 m^3 outriggers, one upstream and one downstream.

Coincidences could be used to measure high energy muons, which are more sensitive to horn shifts.

Nearly portable, could be moved with a crane or forklift.

Could be used as an adjustable muon telescope, moving one outrigger east/west could map out the angular distributions, and placing varying amounts of passive material in between could give a crude energy distributions.

Lack of space in the near hall is an issue.

Something for the beams systematic group to think about…

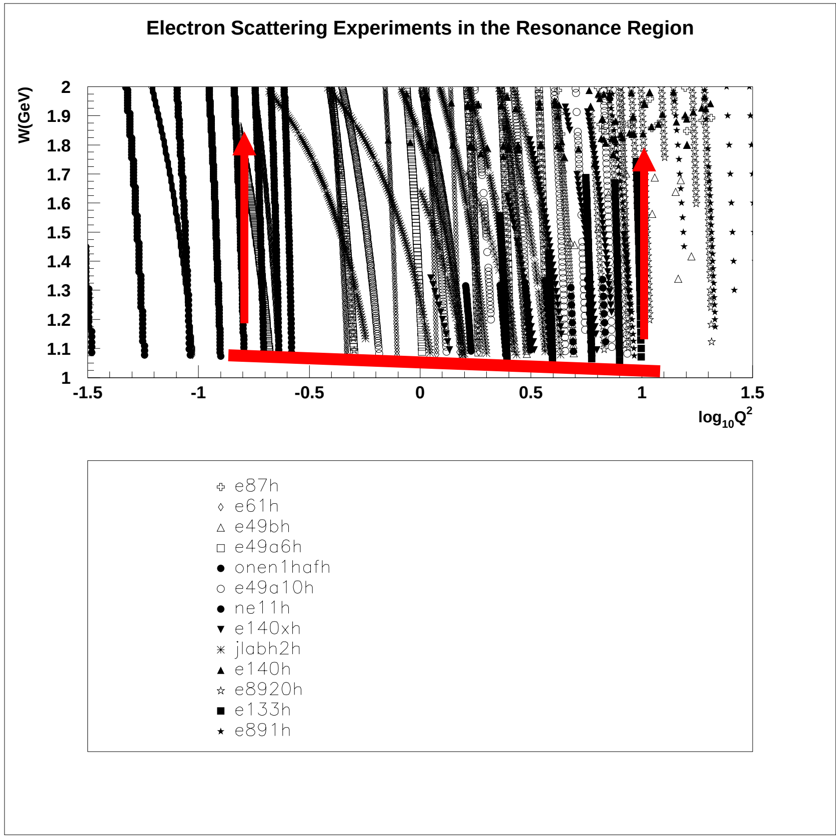
Tuning to Electron Data

The NUMI kinematic range substantially overlaps that studied with high statistics in (e,e') experiments at SLAC, MIT, and the Jefferson Lab.

Comparing to electron data provides a strong constraint on many aspects of the simulation

1) Models for interaction processes
2) Nuclear effects
3) Combining different processes to obtain total cross section over all phase space.

The simplest comparisons can be done with Hydrogen/deuterium targets and allow us to Study (1) and (3) above in detail.



σ_{tot}: σ_{res} for $W<W_{cut}$, σ_{DIS} for $W>W_{cut}$

channel by channel tuning of DIS contributions (NEUGEN)

duality-motivated approaches with new scaling variables (Bodek-Yang)

JLab E03-110

There is a proposal for a new Jefferson Lab experiment to measure inclusive electron scattering off of nuclear targets in the kinematic range important for NuMI. Improving knowledge for future neutrino experiments is the principle motivation.

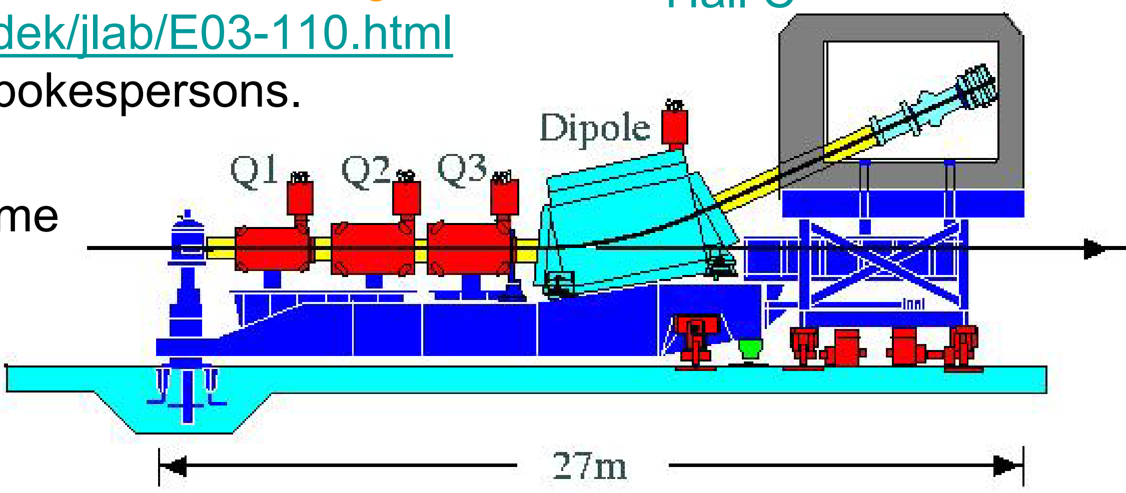
Nailing down the vector part of the hadronic current in this kinematic regime gives a valuable constraint for neutrino models (Rein-Seghal for example).

An extension (5 extra days of beam time) to a planned experiment which will run in 2004.

Presented to the JLab PAC 6/17 – "deferred with regret".
http://www.pas.rochester.edu/~bodek/jlab/E03-110.html
Arie Bodek and Thia Keppel are spokespersons.

Approval expected in January in time for the 2004 run.

Hall C



Reconstruction / Tools

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Costas Andreopoulos: Neural networks and event splitting.

Jim Musser: Track fitting and extrapolat into the spectrometer / spectrometer de-multiplexing. Exercises important elements of the reconstruction framewoı

Tom Osiecki: NC / CC separation and shower finding in the near detector.

Peter Shanahan: Fast MC.

gNUMI → NEUGEN → Fast Detector Response + Energy Smearing → NTUPLES

Randomized shower lengths from GMINOS
Parametrized smearing of energies